Precision and Shifting Effects of Distance Hearing in Listening Tests

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Introduction

This review relates to earlier studies on violins whose specific construction parameters are attributed to foster acoustical intimacy. The related blind test was carried out to answer the question, whether such intimacy would be measurable in terms of perceived distance. Subjects were asked to estimate the perceived distance of a violin played along a discrete scale while they were blindfolded. They were allowed to see the scale and its optional playing positions before and after a series of played sounds. The subjects' distance estimations turned out to be surprisingly accurate. Therefore, despite the analyses on violins, the question of this paper concerns test validity and addresses two questions:

- How does the surprising precision of measured distance perception relate to findings from earlier studies?
- Is there any scale shift, contraction or expansion observable during sessions, as the subjects' visual cue of the room and its scale might fade during a session?

Method

Subjects were asked to estimate the distance of a live-played violin while they were blindfolded. The physical distance between violin player and listener and the choice of violin had been randomly permutated. Preceding listening tests were needed to develop the discrete, non-linear scale with eight positions on a line (see table 1). Close by and far end positions served as guard intervals, and had not been used by the violin player and without the subjects' knowledge. The spacing between positions had been optimized to facilitate statistics of metric scales. Preliminary tests concluded with a specific power function with growing distances between positions. In addition, the spacing between positions was small enough to provide a sufficient and balanced challenge for the listeners, as confirmed by specific statistical measures [2].

position	1	2	3	4	5	6	7	8
distance (m)	4	5	6.4	8.2	10.4	13	16	19.4

Table 1: Distances of the used non-linear scale. Positions 1,2 and 8 served as guard intervals [2]

Subjects had to view and memorize the scale before a series of 10 sounds, called a session. A double session includes a short break for refreshing the visual cue between two sessions. Other independent variables of the test are: two pieces of music, two rooms and pink background noise or silence. The rooms differed in size (room A $2000m^3$, room B $1000m^3$) and reverberation time (room A 1.2s, room B 0.75s). Scale development and distance analyses from the total of 1920 responses from 24 subjects are given in [2].

Results

As a result of the mentioned study, the perceived distance differed only very little from violin to violin. But the perceived distance and the physical distance matched surprisingly well, for both violins and in different acoustical rooms.

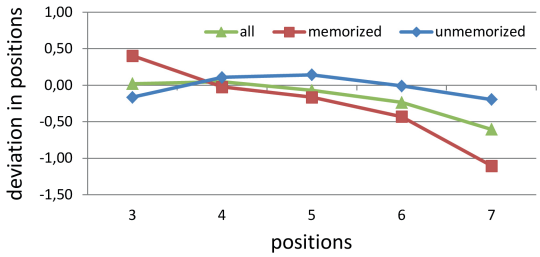

Figure 1: The deviation of the distance estimations from the actual physical distance by means of scale positions. It is showed for early ("memorized"), late ("unmemorized") and all estimations of a series of 10 sounds ("all") [1]

Figure 1 shows the deviation of the subjects' distance estimations from the actual physical distance normalized to the physical distance. E.g. the amount by which sounds presented at position 6 appeared to be closer than the related 13 m (see Table 1) is roughly 0.25 times the distance towards position 5. This amounts 0.25 * 2.6 m = 0.65 m, or, some 5% of the total distance. The deviation of -0.6 at position 7 represents a deviation of approximately -1.8 m at 16 m, or 11,25%. The results for the perceived violin distance are in good agreement with the physical distance.

Figure 1 also includes charts which have been computed by only considering the first three responses of a session ("memorized") or the last three responses of a session ("unmemorized"), for details, see [1]. Comparison of these responses suggest an indication of whether subjects gradually lost the visual cue of the scale. As a result, early distance responses ("memorized") are not as precise as the total average and show a greater compression in terms of overestimations of short and underestimations of long distances. In contrast, responses given at the end of sessions ("unmemorized") show high accuracy and are

even more precise than the average of all estimations.

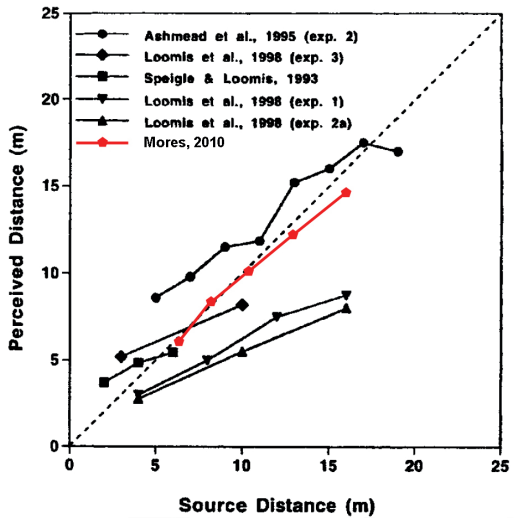

Figure 2: Results of some previous listening tests, which show a similar compression of perceived distance, and this study, which does not show remarkable compression [3]

In the past, similar listening tests on distance perception concluded in most cases with overestimations for short and underestimations for long distances. An extensive summary can be found in [4] and the effective compression of the perceived scale in relation to the physical scale is widely accepted. Figure 2 shows the results of some previous studies indicating the underestimation of far distant sounds [3].

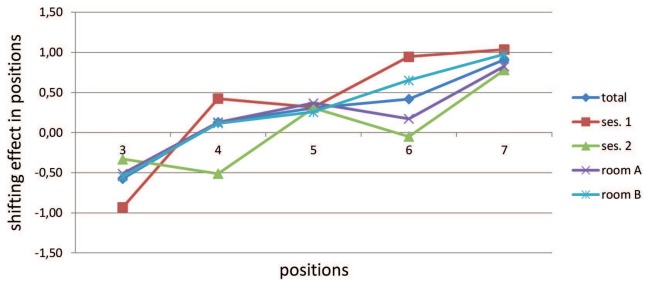

Figure 3: The plotted shift of distance estimations for: different rooms, the first and second session of a double session and the total value, while the subjects are blindfolded. After some sounds the subjects perceive close sounds closer and far sounds increasingly farther [1]

Figure 3 shows the shift of perceived auditory distance from the first three to the last three responses across subjects and sound samples. Again, a negative value represents a shift of perceived distance towards the listener, during the term of the session. At the end of a session and considering all responses ("total"), position 3 was perceived as much as 1/2 a scale position closer than at the beginning of a session. Position 7 was perceived about 1 position farther than at the beginning. This general trend is true for different rooms and while considering responses of 2 subsequent tests on different days [2]. Test repeatability and room independence weaken the arguments of other studies in terms of observed compression between perceived and physical distance.

Discussion

The test results are more precise than results from earlier studies. The generally believed underestimation of far distant sound sources cannot be confirmed when natural sound sources in natural rooms are used. The accurate estimations have been achieved in natural semi-reverberant rooms with a natural stimulus, together with a proper non-linear scale with guard intervals. In the same way micro-movements of the listener's heads facilitate precision in spatial listening tasks, so does the movement of the stimulus, the violin player. Furthermore, the requested response from subjects was not a challenging estimate of absolute distances in meter but a guess of discrete playing positions within a memorized setting.

In contrast, many previous studies used non-reverberant or strongly reverberant rooms in combination with artificial stimuli such as noise or other stimuli radiated from a static loudspeaker. Such artificial context might be too far away from the given human learning base. Many studies used linear scales and scales which suffer from overpopulation at the ends of the scale due to missing guard intervals. Subject responses late in a session are more precise than early ones, and it is unclear whether this is due to periodic learning effects, or whether subjects dared to populate the responses across the entire scale only after gaining some confidence in the course of the session. The latter case would be in accordance with the smaller shift and higher precision of the estimations in session 2 compared to session 1 (see Fig. 3 and [1]).

Conclusion

Results from a study on perceived distance of violin sounds reveal a much higher agreement between perceived and physical distances than most other studies on distance perception. Accuracy is believed to be tributed to using natural sounds in conventional semi-reverberant rooms together with a well-defined discrete scale for subject responses. Comparing responses for sounds early in a session to those late in a session reveals scale expansion, close sources have been rated closer and far sources have been rated farther away than in the beginning. The precision increases over the session, even though the visual cue of the given setup might fade during the blindfolded listening. The generally assumed scale contraction, especially the underestimation of far sources, cannot be confirmed.

References

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